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THE UPPER CRETACEOUS MISSISSIPPI GULF

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DURING the vast interval of time that succeeded the deposition of the latest Paleozoic sediments in the southeastern United States—an interval represented by thousands of feet of marine Triassic, Jurassic and Lower Cretaceous sediments in other parts of the world—this region was above the sea and undergoing denudation, slow at times and quickened at other times according as the topography changed.

This old land surface was the scene of the culmination and final extinction of the pteridosperms, ferns, calamites, lepidodendrons and sigillarias that characterized the flora of the coal measures; of the differentiation and final extinction of the fern and gymnosperm floras of the Triassic; and of the expansion and wane of the cycadophytes which were so extensively developed throughout the world during the Jurassic and Lower Cretaceous. Finally it witnessed the origin and differentiation of the angiosperms or flowering plants—the crowning achievement of plant evolution.

True flowers with gaily colored parts are thus, historically, relatively modern achievements of evolutionary activity, largely the result of the stimulus of insect activity in facilitating cross fertilization. Another feature of the flowering plants is their efficiency in the utilization of sunlight for chemical work. Exclusive of bacteria and their relatives none of the lower plant products can compare in their energy with that stored in the seeds of our cereals, nor with but a few exceptions do the lower plants produce fruits.

One is almost tempted to see design in the world-wide radiation of flowering plants during Upper Cretaceous times immediately preceding the Age of Mammals, and it is an impressive fact that but for the development of the fruits and seeds of the flowering plants during the Tertiary period man could not have progressed beyond the carnivorous pack hunting stage of the older Stone Age and civilization would have been an impossible achievement.

The total thickness of marine sediments of the Triassic, Jurassic and Lower Cretaceous of the world, missing in this area, has been variously considered as amounting to from 12,000 to 40,000 feet and the time involved in their accumulation has been estimated as amounting to at least six million years. This estimate, while it is of necessity far from having an accurate basis, is probably an under rather than an overstatement of the actual time involved.

There is no means for determining how far out on the continental shelf to the southward the coast line extended during these geological periods that are unrepresented by exposed sediments in the southern Appalachian and Eastern Gulf Coastal Plain regions. West of the Mississippi River, however, this geographical history is not an entire blank during this long interval. In the late Jurassic sedimentary records were left in Texas and throughout eastern Mexico, showing that at that time those regions were flooded by the marine waters of the Gulf of Mexico. Again during the Lower Cretaceous the Gulf of Mexico covered much of Mexico, all of Texas and Louisiana, and parts of New Mexico, Oklahoma and Missouri, extending northward into southeastern Arizona and southern Kansas.

Geologists, both in Europe and America, are not in accord regarding the exact time in earth history when the Lower passed into the Upper Cretaceous, although abroad the consensus of opinion seems to be to consider the Cenomanian stage, as it is called, as representing the earliest Upper Cretaceous deposits. In our Western Gulf region, where the Lower Cretaceous is often called the Comanchean system, the later beds referred to the Comanchean—those known as the Washita division—have a wide extent, reaching northward as far as Colorado and central Kansas. These Washita beds carry a marine fauna that is distinctly Cenomanian in type, and the marginal deposits which contain relics of the terrestrial vegetation of that time, as in southern Kansas, furnish a flora that is also distinctly Cenomanian in character. Hence, unless we are to consider that Lower Cretaceous time in this region lasted for thousands of years after Upper Cretaceous time had been inaugurated everywhere else in the world, we are obliged to refer these Washita sediments to the Upper Cretaceous.

The early Upper Cretaceous, or what some students are pleased to call the Mid-Cretaceous, was a time of surpassing interest, not only for the student of earth history, but also for the student of bygone floras. At about this time throughout most coastal regions of the world, the strand commenced one of its periodic invasions of the old land surfaces. Almost everywhere the resulting initial deposits of this transgressing Upper Cretaceous sea were littoral sands with clay lenses, more or less lignite, and containing fossil plants, but no remains of marine life. Whether it is the Perutz beds of Bohemia, the Gredneria sandstone of Saxony, the Atane beds of Greenland, or the sandstone of Mans in France—the latter locality giving its name to the Cenomanian stage—that are considered, all are lithologically much alike and all contain the remains of floras that are very similar throughout and which furnish many identical species of plants. The extent of the Cenomanian sea in southern North America is shown in Fig. 1.

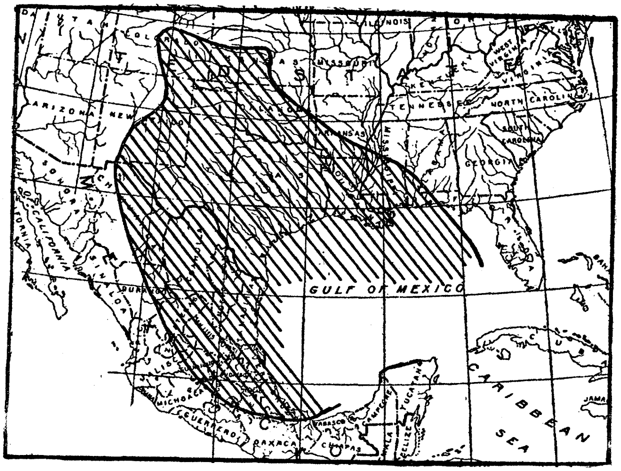

FIG. 1. THE CENOMANIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

In the lower Mississippi valley and the adjacent country to the eastward we find that the long interval during which the land had been above sea level had resulted in the levelling of the country by the slow processes of erosion until the major portion was covered with the products of rock weathering and the surface was approaching a plain that sloped gently toward the southwest. This old plain is known as the Cumberland peneplain. The streams were mature in character, meandering over broad flood-plains and depositing much of their load of sediments somewhere along their courses.

At this time and possibly inaugurated by some slight warping of the crust, or perhaps caused by the actual rising of the sea level, we commence to see indications in the strata that are available for study, of the approach of the strand across southern Mississippi and southwestern Alabama. The oldest known deposits now visible in this region are referred to what is called the Tuscaloosa formation. These are found along the southwestern margin of the present Appalachian valley, Cumberland plateau, and the Interior Highlands to the northwest of the Cumberland plateau. They occupy a roughly lunate area convex toward the southwest. This crescent shaped area of Tuscaloosa deposits extends from near Montgomery, Alabama, to the extreme northwestern part of Alabama, and reaches beyond this point as a thin and narrow band of residual sands and gravels northward across Tennessee and Kentucky.

At about the center of this crescent the outcrop of these deposits broadens until it is nearly fifty miles wide. The materials are prevailingly sandy—light-colored, micaceous, irregularly bedded sands with heavy beds of gravel made up of well rounded quartz and subangular chert pebbles. In disconnected and interbedded lenses are laminated or at times massive dark to variegated clays. Some layers are filled with the prostrate logs of drift wood, often of large size; thin bands of lignite are present at various levels, and occasional thin layers are glauconitic sands full of comminuted vegetable débris. No fossil remains have been discovered in these beds except the impressions of land plants and these are usually much broken, presumably because of their having been drifted in river waters. Occasionally more perfect materials are discovered that evidently accumulated in the quiet back water of rivers or in ponds, and that grew near at hand.

The Tuscaloosa formation is usually considered as having a thickness of about 1,000 feet, but this is calculated and not observed. Its basis is the usual method of calculating the thickness of a normal marine formation by the dip of the beds and the width of the outcrop, a method not applicable to the Tuscaloosa since it is obviously not a normal marine deposit. One can not study the Tuscaloosa with its clay lenses, its obliquely crossbedded sands, the abundance of drift wood, prevailing coarseness, widely disseminated vegetable matter, and occasional traces of glauconite, without becoming impressed with its delta-like character. It fulfils all of the requirements of a delta deposit and answers to none of the criteria of a normal marine or estuarine deposit. This obviously does not mean that at its seaward margin it did not merge into littoral, estuarine and lagoonal environments, or that on its landward side it did not extend up the river valleys as fluviatile, lacustrine, and typical continental deposits. All of these types were doubtless being formed contemporaneously and over a long interval of time, that is to be measured by the area over which this delta-like blanket was spread rather than by the actual thickness of the sediments at any one locality. Formerly estuary conditions were considered as explaining the method of deposition of this and of similar deposits everywhere that lacked marine fossils, but there is usually but slight basis for predicating such an environment. More important were bayous, swamps, sand beaches, lagoons behind barrier beaches, and the various types of continental deposition.

The streams which brought in the sands, driftwood and carbonaceous muds came from the northeast and the bulk of the drainage of the Appalachian interior country, now a part of the Tennessee River system, flowed to the southwest at that time, the delta distributaries being located in the region where the Tuscaloosa formation is found to be thickest and its outcrop widest.

West of the Mississippi River at that time the shallow Cenomanian or Washita sea was having its margins silted up and was gradually withdrawing to the southward, leaving in its wake a mantle of littoral sands that now form a lower part of what is called the Dakota sandstone. The time when this withdrawal of the Washita sea reached its maximum corresponds approximately with the oldest known part of the Tuscaloosa delta or deltas—for there may well have been a series of deltas along this old coast. As seems to be true of all geological history the coast line, so impressive and seemingly permanent a geographical feature, did not remain in a definite position for a long time in the geological sense, but after its withdrawal it commenced a second readvance to the northward, and with this event we reach the time at which we took up the history of the Tuscaloosa delta.

As this sea advanced over the Western Interior region it formed a second mantle of littoral sands that constitute the remainder of what we now know as the Dakota sandstone, which thus becomes progressively younger in its upper portion as it is traced toward the northwest. Overlying these beach sands are normal marine shales which were also being deposited in the south earlier than in the north. The history of this Western Interior sea is beyond the scope of the present article, suffice to say that it eventually became one of the most widespread floodings of the continent that we can trace, and may even have extended until the waters of the Gulf of Mexico mingled with those of the Arctic Ocean. It broadened out medially until its opposite shores were respectively in Idaho and Utah on the west and in Minnesota and Iowa on the east. Its history was long continued and complicated, and the shores of its prevailingly shallow waters were ever shifting. Concomitant with the advance of this Benton sea as it is called over the Great Plains and Rocky Mountain country we see signs on an incipient embayment extending up the Mississippi Valley.

According to the cosmopolitan terminology of geology this stage of Cretaceous history is known as the Turonian stage from the typical development of its deposits in Touraine, and

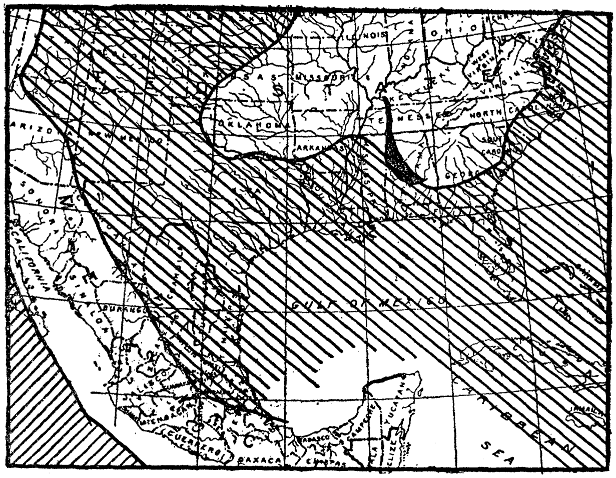

FIG. 2. THE TURONIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

the geography of that time in southern North America is shown in Fig. 2, the area occupied by the Tuscaloosa delta deposits being indicated by solid black.

The Tuscaloosa delta deposits with their contained fossil flora merge along their seaward margin into marine sands and black laminated clays known as the Eutaw formation, which is then partially contemporaneous with the Tuscaloosa. Higher in the Eutaw occur massive glauconitic and more or less calcareous fossiliferous sands which have been called the Tombigbee sand member of the Eutaw formation because of their development along the Tombigbee River. This sand facies of the Eutaw seems to have been a truly transgressive marine deposit comparable with the Benton of the Western Interior sea. It eventually extended up the Mississippi embayment well across the state of Tennessee. Meanwhile history was not standing still in other regions. The warping of the surface which made it possible for this arm of the sea to extend up the Mississippi valley was naturally not without its effect upon the tributary rivers, and we assume that the Upper Cretaceous

Tennessee River had its southern distributaries silted up and gradually shifted its outlet northward. This can not be demonstrated conclusively, but the fact that the Tuscaloosa sands and gravels can be traced far to the northward along such a probable path, and the fact that these Tuscaloosa sediments in Tennessee are younger than the bulk of the Tuscaloosa deposits farther south as shown by the fossil plants points to such a conclusion. This is rendered still more probable by the additional fact that the upper Eutaw becomes more and more calcareous and finally passes into an argillaceous limestone or calcareous clay of great purity and thickness known as the Selma chalk. In this southern region immediately outside of the lunate area of maximum development of the Tuscaloosa delta deposits and separated from them by only a narrow band of Eutaw deposits there lies a similar lunate area of Selma chalk. Here the latter forms a broad band upwards of 1,000 feet in thickness and continues to the top of the Upper Cretaceous, being immediately overlain by the Eocene. Traced either eastward or northward toward the horns of the crescent the Selma chalk becomes more and more impure until it is replaced along the strike by sands and clays which have received the name of Ripley formation.

The numerous oyster-like and other Mollusca found in the chalk show that it was a shallow water deposit. It contains a very minor percentage of sandy sediments and no drift wood or other land-derived material. The bearing of this is obvious, for if the stream or streams that built the Tuscaloosa delta or deltas still flowed where they had formerly done there would have been no Selma chalk, but these slowly accumulating calcareous muds would have been completely masked by the coarser terrigenous materials brought in by the rivers. Even if a great reduction in run off be postulated, the streams would at least contribute seasonal loads of coarse sediments and the vegetable débris that such slow streams invariably carry would demonstrate their existence by lignitic laminae or by carbonaceous clays in the chalk, and these are not found. The conclusion is inevitable—that at the time the Selma chalk was being deposited the drainage of the eastern shore of the Mississippi embayment was to the northwest and southeast, where the chalk is replaced by sands and not where it had been during Tuscaloosa time.

This northward advance of the Upper Cretaceous sea up the Mississippi valley continued while the Selma chalk was being deposited farther south where its waters were clearer until finally a broad gulf was formed which reached well into southern Illinois beyond the present mouth of the Ohio, submerging all of Louisiana and Mississippi, western Tennessee and Kentucky, southeastern Missouri, more than half of Arkansas, and the greater part of Texas except the *Llano estacado* region, which then formed a barrier that almost cut off the Mississippi embayment from the Western Interior sea.

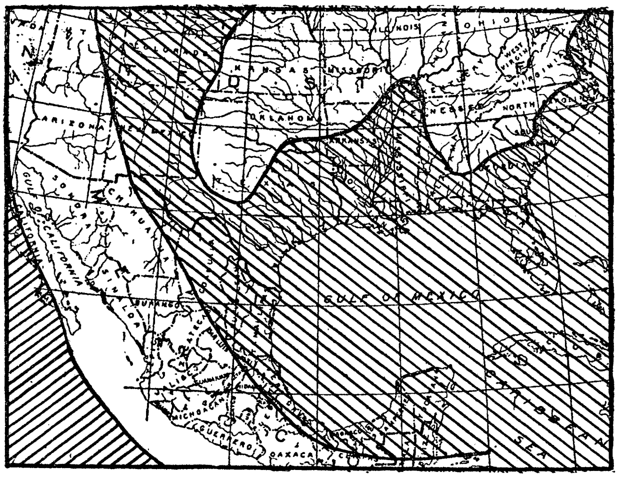

FIG. 3. THE RIPLEY OR EMSCHERIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

This stage of Cretaceous history is commonly known as the Emscherian or lower Senonian stage, and the geography of that time in southern North America is shown in Fig. 3. This geographical change quite naturally had a profound influence upon the fresh-water inhabitants of the regian, and the striking contrasts between the Naiadaceæ or fresh-water pearl shells of eastern and western North America so pronounced to-day is supposed, whether rightly or wrongly it is hard to say, to date from this invasion of the sea during the Upper Cretaceous.

After this maximum advance of the Gulf of Mexico up the Mississippi valley a recession commenced which is marked by the increasingly near shore and shallow water character of the deposits, with leaf bearing clays deposited in lagoons and estuaries, with many near shore- and mud-loving molluscs like *Corbula.* Only occasionally do we find traces of a normal marine fauna of clearer waters like that found at Owl Creek in Mississippi or along Coon Creek in Tennessee. A limited area in the lower part of the Ripley sands at Coon Creek in the northeastern part of McNairy County, Tennessee, has furnished a wonderful assemblage of marine fossils. Already it has yielded the remains of three species of fishes, five crabs and nine sea mats (bryozoa), one sea urchin, two worms, one coral and a vast host of mollusca. It has furnished what is probably the most prolific molluscan fauna that has as yet been found anywhere in our American Cretaceous, since about 350 different forms have already been recognized. Gastropods are especially abundant, embracing about 75 genera and 150 species, of which about one third are new to science, and all are beautifully preserved. This fauna contains seven Cephalopods, among which is a veritable giant of a baculite or armored squid. A mounted specimen of one of the more complete of these baculites, but not the largest that has been found, has been mounted in the Johns Hopkins Paleontological collections.

Finally, this region covered by the Upper Cretaceous Mississippi Gulf was entirely drained and remained above the sea for a long interval of time until it was covered once again by a similar transgression of the Gulf of Mexico in lower Eocene (Midway) time. Meanwhile a complex succession of events was taking place in the Western Interior sea. Its shallow marginal waters were repeatedly silted up and converted into coastal swamps in which the luxuriant vegetation of that time went to form the lignitic coals that are so widely distributed in our prairie states. Traces of this sea lingered for a long time in the deeper parts of the basin after most of the area had been transformed into a region of continental and palustrine deposition, and these conditions persisted for a long time after the Mississippi embayment had been drained.

Because of the more favorable conditions for the accumulation and preservation of the remains of the contemporaneous Upper Cretaceous floras, that of the Tuscaloosa is the most extensive and representative of any of the floras of the Upper Cretaceous Mississippi embayment deposits. This Tuscaloosa flora as it is known at the present time comprises over 150 different species, none of which survived in the Eocene of this region. Of the 87 known genera over half are now extinct, while others are no longer represented in North America, but have their surviving descendants in South America, the Orient, or even the antipodes. These 87 genera represent 48 families and 31 orders. The largest alliances are the Ranales (buttercup, custard apple, magnolia order) with 26 different species, the Rosales (rose order) with 15 species, the Sapindales (soapberry order) with 15 species, the Coniferales (conifer order) with 14 species, and the Urticales (fig, bread fruit order) with

8 species. One hundred and twenty-three of the Tuscaloosa forms are dicotyledons, similar to our modern hardwood trees, and of these 107 belong to the more primitive choripetalous division, while only 16 belong to the more specialized gamopetalous division. The largest single genera are *Celastrophyllum, Magnolia* and *Ficus.*

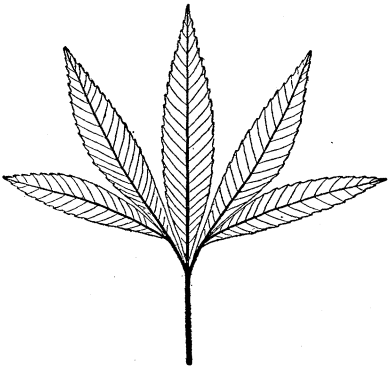

FIG. 4. LEAF OF *Dewalquea,* an extinct genus of Upper Cretaceous plant, found in the Tuscaloosa delta deposits of Alabama.

One of the most puzzling of the Tuscaloosa plants is shown in the accompanying figure (Fig. 4). The leaves were digitate and are seen to consist of a central symmetrical terminal leaflet and a pair of inequilateral leaflets on either side of the central one. These leaves are very abundant in the younger beds of the Tuscaloosa toward their seaward margin. It was not difficult to give them a name since they correspond generically with leaves found elsewhere in both Europe and America which were named by Saporta and Marion Dewalquea in honor of the Belgian geologist Dewalque, who first discovered them at Gelinden near Liège. Their botanical relationship, however, has never been satisfactorily determined. Saporta and Marion thought that they were related to the Hellebore tribe of the family Ranunculaceæ, while others consider that they are referable to the Aralia family (Araliaceæ) or the Bombax family (Bombacaceæ). This form, so common in the upper Tuscaloosa, has also been found in Tennessee and South Carolina, and other species are known from Arkansas, Wyoming, New York, New Jersey, North Carolina, Minnesota, Kansas, Belgium, Germany, Bohemia and Greenland, showing that it was evidently a widespread plant type during Upper Cretaceous times.

An element in the Tuscaloosa as well as in the Eutaw and Ripley floras, one that is no longer found in North America except along the Mexican border is the Cæsalpinaceous genus *Bauhinia,* now confined to the tropical and sub-tropical regions of America, Asia, Africa and Australia. Experience has shown that such modern genera as are represented in all or several tropical regions of the world necessarily have had a long geological ancestry which has enabled them to reach their present striking confirmation of this theoretical consideration. Upper Cretaceous species, recognized by their very characteristic leaf form, have been found in both Europe and America, and Tertiary species are recorded from southern Europe. About a dozen fossil forms are known and they are especially abundant

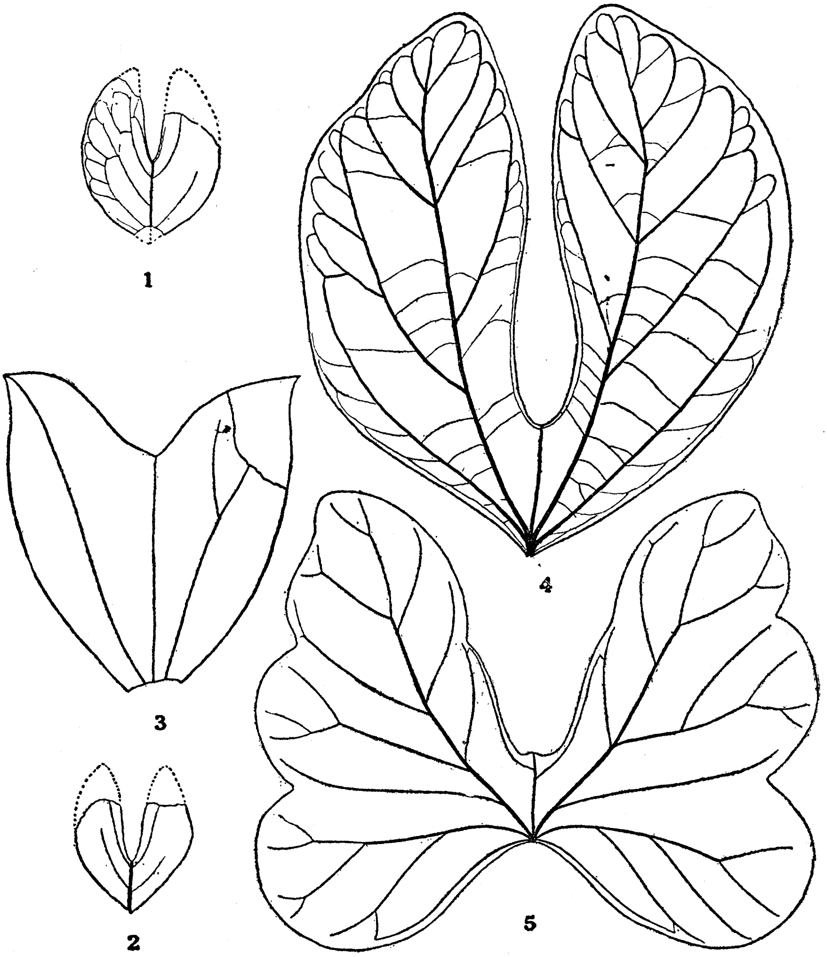

FIG. 5. LEAVES OF VARIOUS UPPER CRETACEOUS BAUHINIAS. 1, 2, *Bauhinia marylandica* Berry from the Magothy formation of Maryland; 3, *Bauhinia ripleyensis* Berry from the Ripley formation of Alabama; 4, *Bauhinia cretacea* Newberry from the Raritan formation of New Jersey; 5, *Bauhinia alabamensis* Berry from the Eutaw formation of Alabama.

and varied in the North American Upper Cretaceous. They seem to have been particularly common during Tuscaloosa time, for at several localities in Alabama leaves of both a large and a small species have been discovered which are also found at corresponding horizons in Maryland and New Jersey. In the lower Eutaw a large and ornate butterfly-like form has been collected, while a smaller form is present in the Ripley in both Alabama and Tennessee. These are all shown in the accompanying figures.

Another Tuscaloosa plant belonging to the same family as *Bauhinia* and somewhat like it in leaf form is *Hymenæa*. The latter has leathery leaves with a characteristcally different venation and entirely divided to form two inequilateral leaflets. The modern species are trees of the American tropics yielding a variety of copal gum and a hard red wood. They are prized by the South American Indians for their sweetish sour fruits. Not more than eight or ten existing species are known, so they are less than twice as numerous as the known fossil species. In Upper Cretaceous and Tertiary times the genus was represented upon both sides of the Atlantic. Five different forms are recorded from beds of about the same age as those of the Tuscaloosa in Kansas, New Jersey, New York and Bohemia. The Tuscaloosa plant is the handsomest and most clearly defined of any of these.

Several species of *Sequoia* grew round the shores of the Mississippi embayment throughout the Upper Cretaceous, as they had in still earlier times, but the presence of sequoias is not as remarkable as it may seem to the layman who knows only the giant trees and the California redwood of recent times, for sequoias were once cosmopolitan and their foliage or characteristic cones are found in the Mesozoic and Tertiary rocks of most countries where the fossil floras have been studied. There are, however, two other types of Tuscaloosa conifers that deserve special mention.

The first of these is *Dammara* (and *Protodammara*). The modern dammaras or kauri gums comprise several species, mostly insular types, found in the area extending from the Philippines and Malay Peninsula through the East Indies to Fiji and northern New Zealand. They have mostly large, parallel-veined leaves and immense cones of single-seeded deciduous scales. Sometimes in Tertiary rocks, but especially in those of the Upper Cretaceous, kite-shaped mucronate tipped cone scales with longitudinal resin canals have been found. These baffled paleobotanists for a long time, but are now known to be those of *Dammara* and of an allied extinct genus *Protodammara* which had smaller and three-seeded cone scales. Both of these occur in the Tuscaloosa clays as well as in corresponding horizons northward as far as western Greenland and abodes over land routes no longer in existence. *Bauhinia* is a in Europe. These occurrences prove that this now restricted type of ancient conifer was once common throughout the northern hemisphere and has gradually become restricted to its present limited habitat.

The other Tuscaloosa coniferous type that I wish to mention is *Widdringtonites,* a genus whose descendants are now confined to South Africa and Madagascar with outlying relatives in North Africa, extreme southern South America and Australia. Although foliage like that of *Widdringtonites* is recorded from rocks as old as the late Triassic, it should be remembered that coniferous foliage alone in the absence of cones is difficult to identify with precision, and while *Widdringtonites* has been identified with very many Upper Cretaceous and Tertiary outcrops in North America, Greenland and Europe, they are not all above suspicion. However, if the student is fortunate enough to discover the cones, he can be assured of the nature of his finds, for *Widdringtonites* has characteristic four-valved cones quite distinct from those of other conifers. Among the great abundance of delicate foliage of this plant preserved in the Tuscaloosa clays of Alabama are some with small, attached four-valved cones just like those of the modern forms, thus demonstrating their relationship.

One of the most spectacular members of the Eutaw and Ripley floras is the plant known as *Manihotites georgiana,* shown in the accompanying figure (Fig. 6), one fifteenth natural size. These leaves are subpeltate and of enormous size, deeply lobate and dichotomously sublobate. Naturally, when such large leaves fell into the bayous of Eutaw and Ripley time and drifted out to be buried in the mud of the lagoons, they were almost always broken to pieces, and such fragments are not uncommon and are rather widely distributed, having been found at several localities in North Carolina, Georgia, Tennessee and Arkansas. It would have been entirely impossible to determine their general form or their botanical relationship if it had not been for the accidental discovery by the writer of two nearly perfect leaves in a tiny clay lens in the lower Eutaw sands of western Georgia.

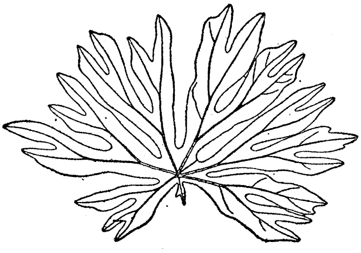

FIG. 6. *Manihotites,* AN UPPER CRETACEOUS CASSAVA LEAF FROM THE EUTAW FORMATION OF GEORGIA. × 1/15.

One of these leaves measured 36 centimeters across and the other 48 centimeters and both apparently came from the same plant. It was at once obvious that they represented an ancestral type of the genus *Manihot,* which includes the Cassava plant, and which has upward of a hundred existing species, nearly all of which are endemic in tropical South America, the majority being found in Brazil. Various of the cultivated varieties will grow in our southern gulf states where the growing season lasts for nearly the whole year, but light frosts or even continued cool weather entirely stops growth. Even in the tropics the best growth is made in the humid coastal regions, so that if the fossil form required a comparable habitat and climate, it furnishes an interesting light on the conditions around the border of the Eutaw and Ripley seas of the Mississippi embayment.

Many other interesting extra-limital types might be mentioned which once flourished in association with the early ancestors of our native trees on the shores of these ancient seas, but enough has perhaps been written to illustrate the fascination in transporting the mind backward through millions of years, forgetful of the obtrusive present, and endeavoring to picture the pulsing life and its environment and the shifting scenes of the geographic history of remote time.